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A BAKEABLE THERMISTOR VACUUM GAUGE

by

R. W. Roberts, P. E. McElligott, and G. Jernakoff

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ABSTRACT

A thermistor detector for measuring pressures in the range 10^{-4} to 1 torr is described. This gauge operates at constant temperature ($\sim 100\,^{\circ}C$), has a small volume, and presents an innocuous surface to the vacuum system. This gauge is very stable, maintains its calibrations after a 450°C bakeout, and is suited for use in ultrahigh vacuum systems. Operating characteristics are described.

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INTRODUCTION

Vacuum gauges that operate over the pressure range 10^{-4} to 1 torr are available in a variety of designs.(1) The incorporation of these gauges in ultrahigh vacuum systems requires that they retain their calibration after high-temperature bakeout (200° to 450°C) and that they do not contribute gas to the system.(2) In many adsorption experiments, it is necessary that the pressure sensing gauge have a small volume, operate at low temperature (~100°C), and contain no reactive metals. This is particularly important for experiments dealing with the adsorption of hydrocarbons on clean metal films.(3, 4)

The use of thermistors for pressure measurement has been considered by others;(1, 5, 6) however, their devices do not operate at a constant temperature, nor has performance in bakeable, ultrahigh vacuum systems been evaluated.

We have developed a thermal conductivity gauge that satisfies the above requirements.* It employs a glass-coated bead thermistor detector that operates at a constant temperature (~100°C) and maintains its calibration after bakeout at 450°C.

EXPERIMENTAL

Gauge Tube

The pressure sensing device is a glass-covered bead thermistor (GE type 1B 153), which is spot welded to glass-covered Fernico or tungsten leads in a 1-cm-diameter glass tube (Fig. 1). The tube is thermostated in a constant temperature bath, usually a mixture of ice and water (0°C). The volume of this gauge tube is about 10 cm^3. Of course, the configuration of the gauge may be altered to conform with requirements of each experimental situation.

Electronics

The thermistor gauge circuit, Fig. 2, is designed to operate with thermistor beads whose resistance is less than 1000 ohms at 100°C. The circuit consists of a closed loop regulator that senses the bridge unbalance voltage and readjusts the voltage to the bridge so as to bring it back into balance. Since the thermistor bead is one leg of the bridge circuit, sufficient power is supplied to the bridge input to maintain the thermistor bead at constant temperature of approximately 100°C.

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*Patent applied for.

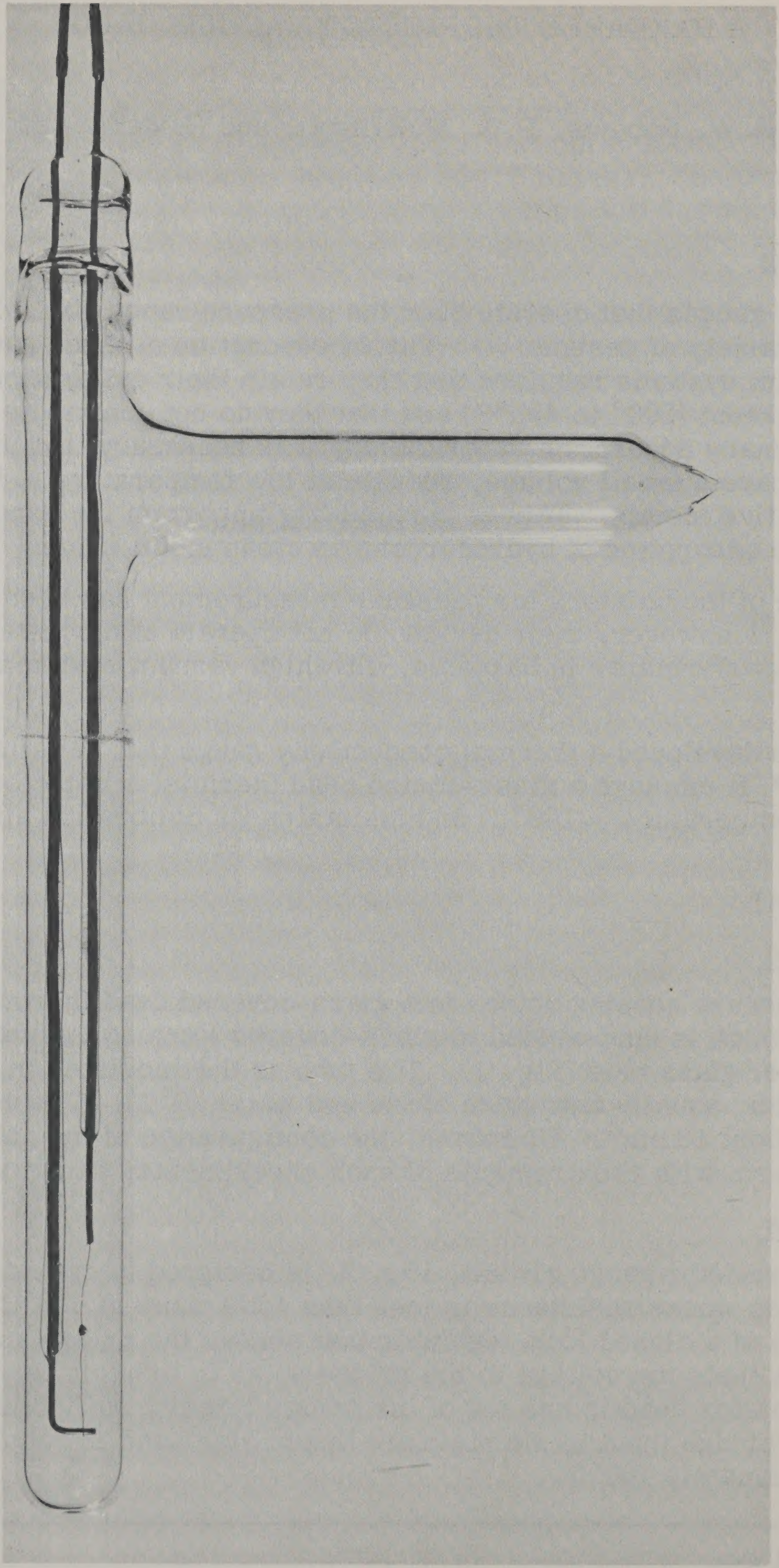

Fig. 1 Thermistor vacuum gauge.

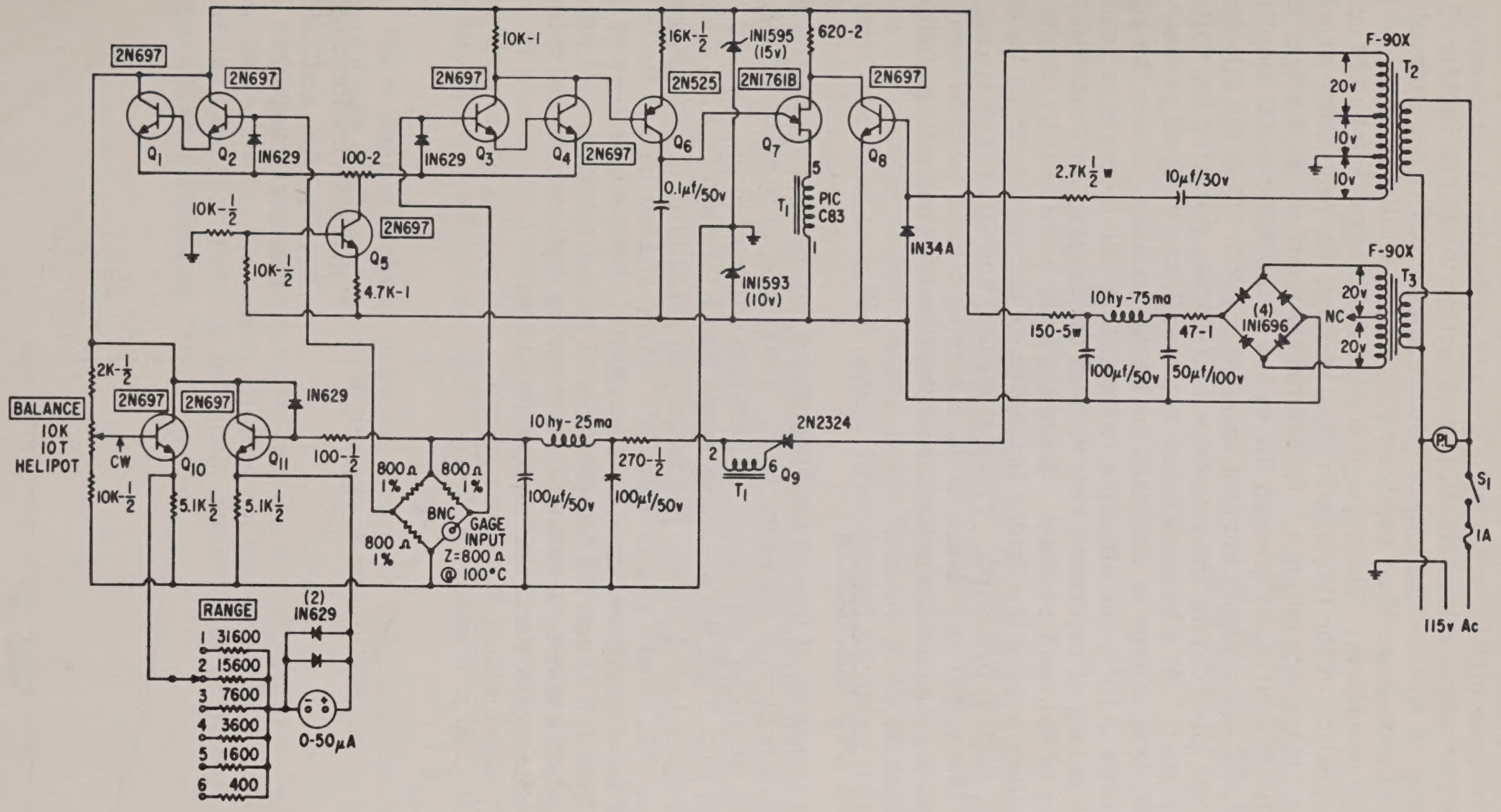

Fig. 2 Schematic diagram of electronic circuit used with thermistor vacuum gauge.

The operation of the complete circuit is as follows: initially the thermistor resistance is quite high (15 kohm at 25°C), and the bridge is unbalanced. The differential amplifier output allows the 0.1 μf capacitor to charge rapidly (0.1 msec) to approximately 15 volts. The unijunction transistor (Q7) fires immediately turning the silicon-controlled rectifier (Q9) on for a full half-cycle of the 60-cycle voltage waveform. The voltage across the bridge thus builds up rapidly. As the self-heating of the thermistor bead occurs, its resistance drops rapidly, bringing the bridge into balance. As the bridge approaches balance, the capacitor charging rate is decreased through the action of the differential amplifier (Q1 through Q5) and the constant current transistor (Q6). Thus the silicon-controlled rectifier fires later during the allowable half-cycle, reducing the voltage across the bridge circuit. At a balance there is a small error signal present that calls for just sufficient voltage to maintain the bridge balance. Since the gain of the circuit is large ($> 10^4$), the effective resistance of the thermistor bead is nearly equal to the values of reference resistors of the bridge, thus maintaining the temperature of the bead constant. Since the bead loses heat by conduction to the gas, the voltage across the bridge increases or decreases for an increase or decrease in system pressure. Transistors Q10 and Q11 are used as emitter followers to supply a low output impedance to the metering circuit used to monitor the voltage level supplied to the bridge from the filter. This voltage indicates the system pressure.

OPERATION AND DISCUSSION

The response of this gauge depends on the thermal conductivity of the gas and the geometry of the gauge tube. Therefore, it must be calibrated with an absolute gauge for each gas. Calibration curves for H_2, O_2, Ar, and Xe are given in Fig. 3 for the pressure range 0 to 1 torr and in Fig. 4 for the pressure range 0 to 0.1 torr. The maximum sensitivity of this device for Xe, Ar, O_2, N_2, CH_4, and C_2H_6 is about 10^{-4} torr, and for H_2 and He is about 10^{-5} torr. A McLeod gauge was used as a standard. The temperature of the thermistor bead was about 100°C and the temperature of the surrounding walls was 0°C. A higher sensitivity may be achieved by increasing the temperature difference between the thermistor and the surrounding glass.

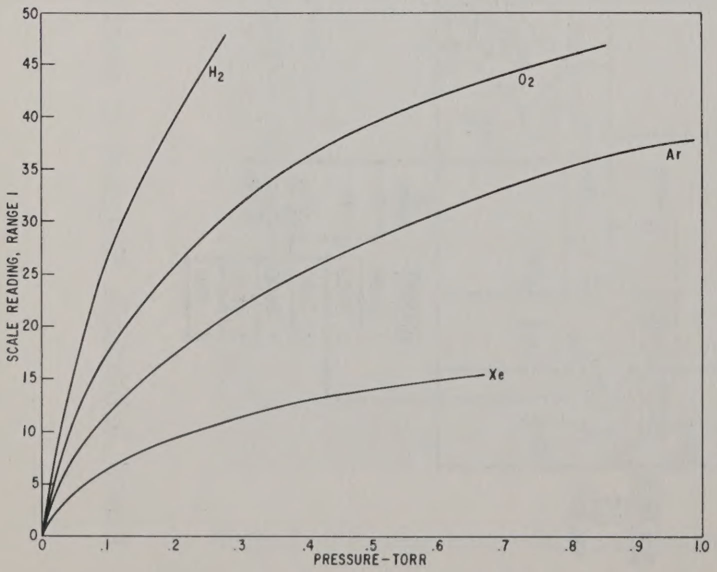

Fig. 3 Calibration curves for H_2, O_2, Ar, and Xe over the pressure range 0 to 1 torr.

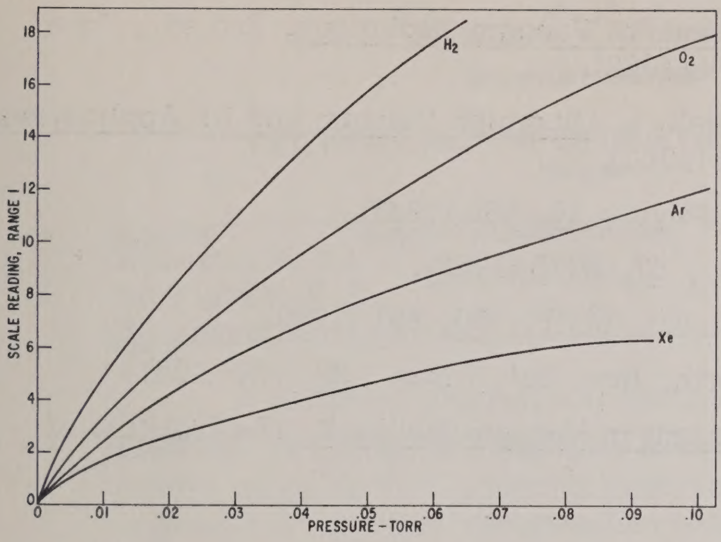

Fig. 4 Calibration curves for H_2, O_2, Ar, and Xe over the pressure range 0 to 0.1 torr.

We have observed that the calibration agreement among different gauge tubes with approximately the same dimensions is very good, usually within 2%.

It has also been established that the calibration of the gauge is not altered by high-temperature bakeout. After 15 hours at 450°C a gauge tube was recalibrated and found to agree, within experimental accuracy (2%), with the calibration before bakeout.

In general, the output of the bridge is adjusted to zero when the pressure in the system is below 10^{-5} torr. It is observed that the zero setting is very stable over a period of several days. The maximum variation that occurs is ±2 small divisions on the most sensitive range, position 6. This corresponds to a variation in pressure of about $\pm 5 \times 10^{-5}$ torr for most gases.

The response time of the gauge was measured by placing the thermistor bead in the low-pressure end of a miniature shock tube and displaying the gauge response on an oscilloscope. The shock tube was so designed that pressure equilibrium was established within 50 msec after puncturing the diaphragm. The response time of the gauge, i.e., time to reach 90% maximum amplitude, was found to be ~0.4 second and was independent of pressure in the range 0.05 to 0.4 torr.

There does not appear to be any change in the characteristics of the thermistor gauge after long (months) periods of use. Calibration curves are very reproducible.

This thermistor detector presents a low-temperature, innocuous surface to the vacuum system. Therefore, it does not interact with reactive gases. Also its properties, and therefore its response, are not altered by surface reactions that plague hot wire detectors.(7)

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